



Fermi

Gamma-ray Space Telescope

DISCOVERY OF A
YOUNG GAMMA-RAY
PULSAR ASSOCIATED
WITH AN EXTENDED
TeV GAMMA-RAY
SOURCE

Michael Dormody

Santa Cruz Institute For Particle
Physics

dormody@scipp.ucsc.edu

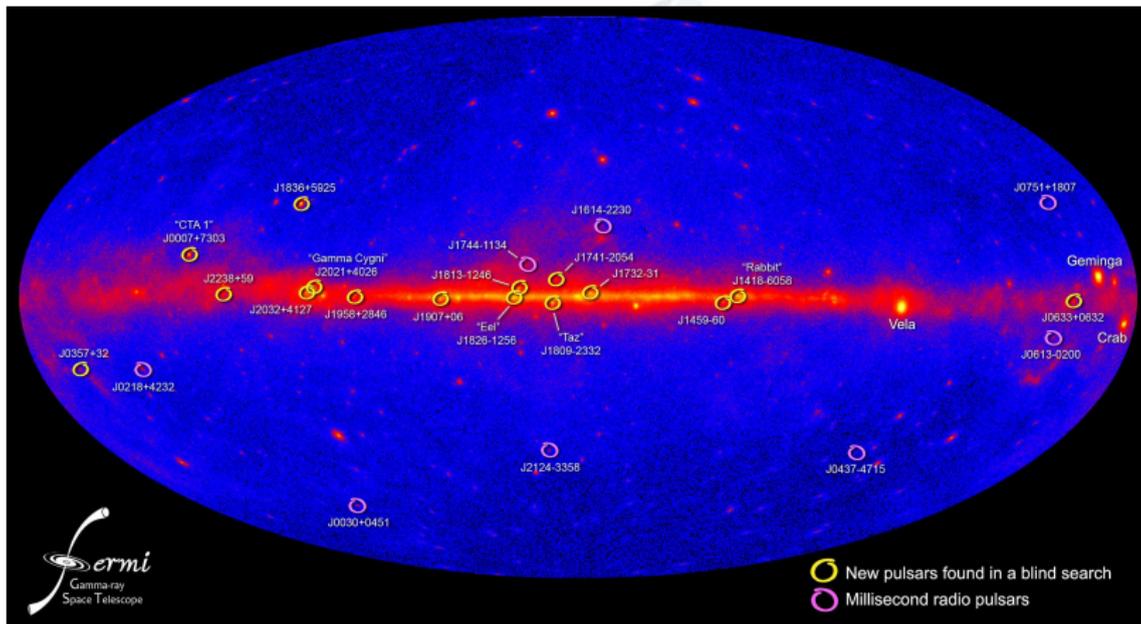
on behalf of the Fermi LAT
collaboration

Fermi Symposium,
Washington DC, November
4, 2009

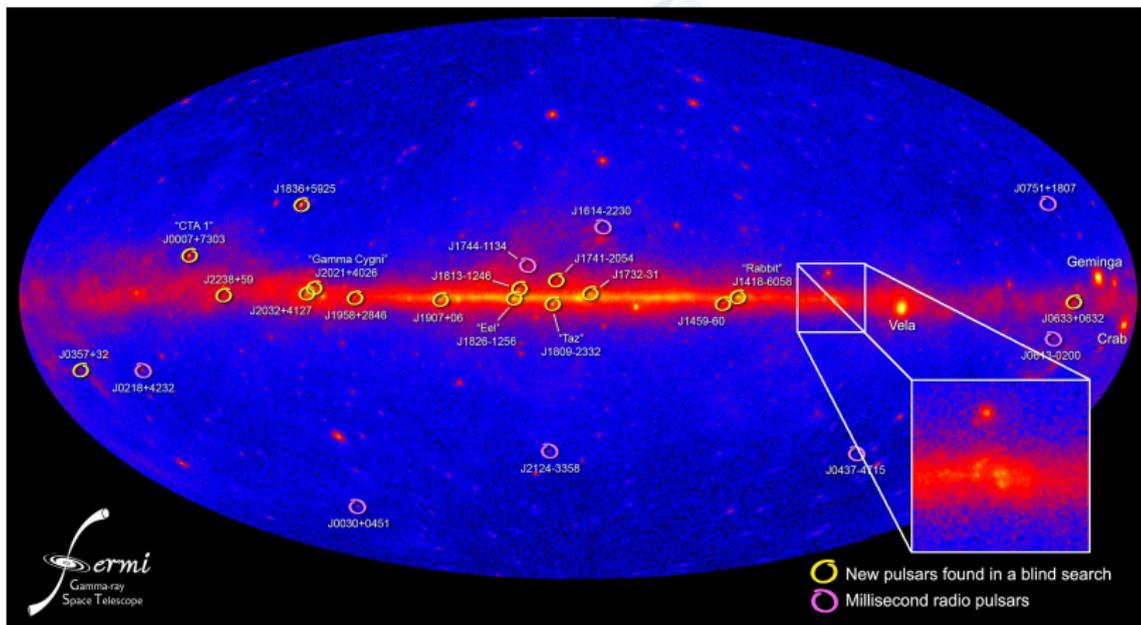
- ▶ Pulsars in the gamma-ray sky
- ▶ Measuring pulsations in a blind frequency search
- ▶ New pulsar announcement: PSR J1022-5746
 - ▶ Timing parameters
 - ▶ Distribution in current population
 - ▶ Pulse profile
- ▶ Multiwavelength Observations
 - ▶ TeV: HESS J1023-575
 - ▶ X-ray: Chandra

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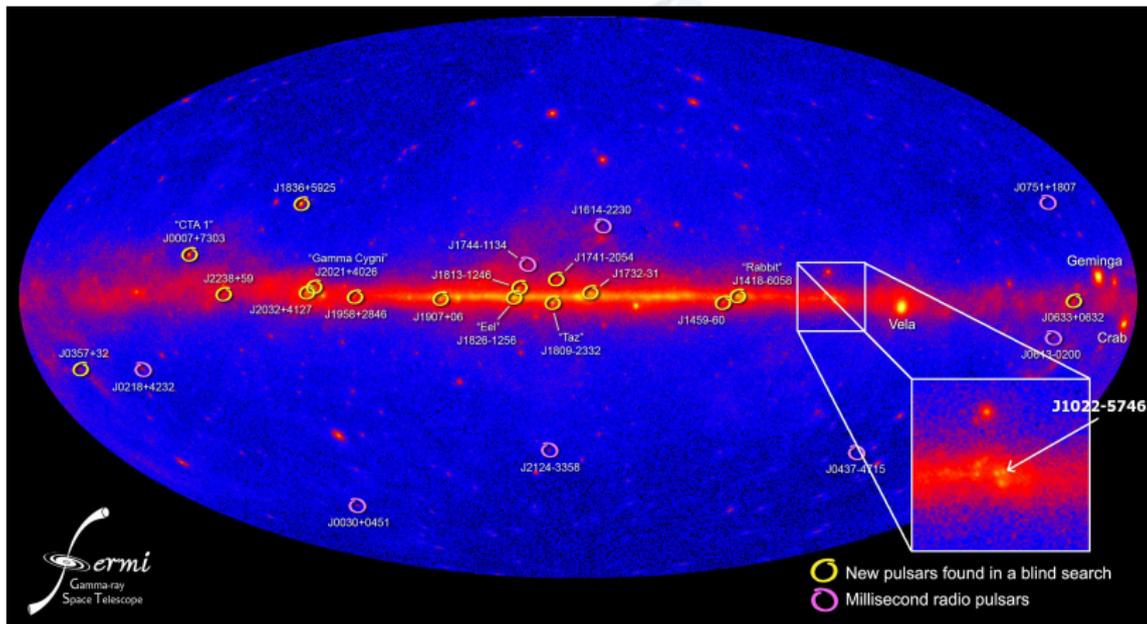
THE GAMMA-RAY SKY ACCORDING TO FERMI



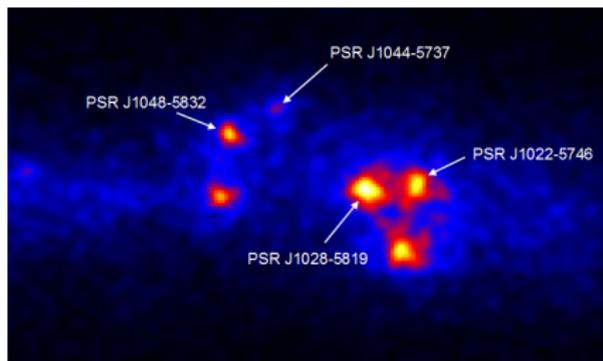
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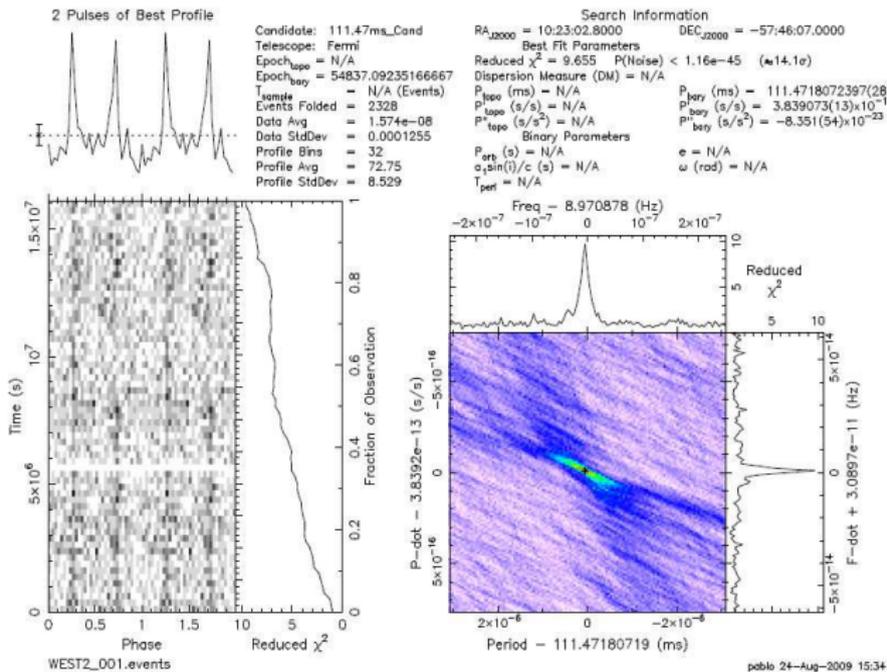


DETECTING THE PULSAR IN A BLIND SEARCH

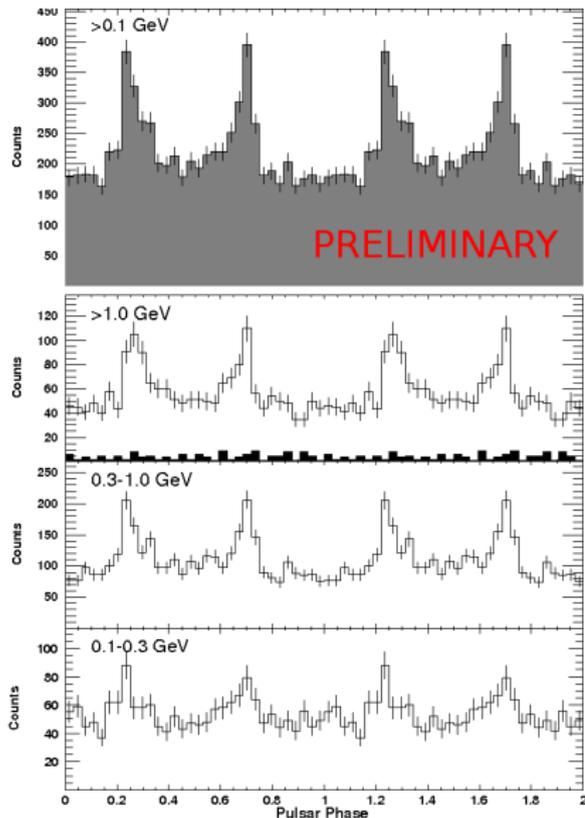


- ▶ Found early in mission as a bright gamma-ray source: 0FGL J1024.0-5754.
- ▶ Early localization not precise enough for pulsation detection.
- ▶ We look for periodicity in sparse gamma-ray data using the *Time Differencing Method* (Atwood et. al. 2006).
- ▶ We step from zero spin-down to the spin-down of the Crab ($\dot{f}/f = -1.125 \times 10^{-11} \text{ s}^{-1}$).
- ▶ $R = 0.8^\circ$, $E_{min} = 300 \text{ MeV}$, *Diffuse* class photons.
- ▶ PSR J1022-5746: youngest and most energetic gamma-selected gamma-ray pulsar!
- ▶ Very young pulsar ($\tau_C \sim 4.6 \text{ kyr}$). Requires an \dot{f} correction in timing solution.

PULSAR DETECTION AND PHASE EVOLUTION



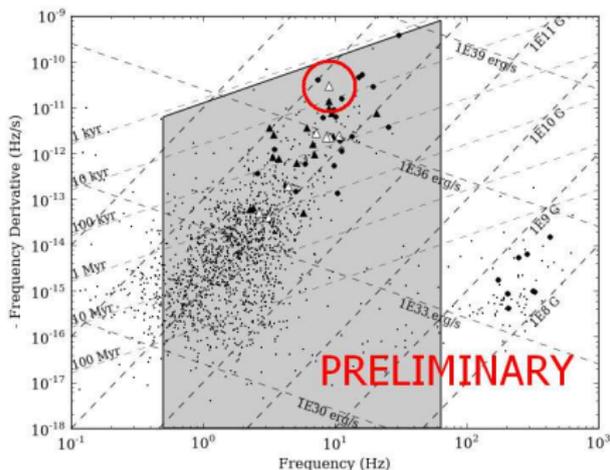
PULSE SHAPE PARAMETERS



Double peak structure seen across multiple energy bands.

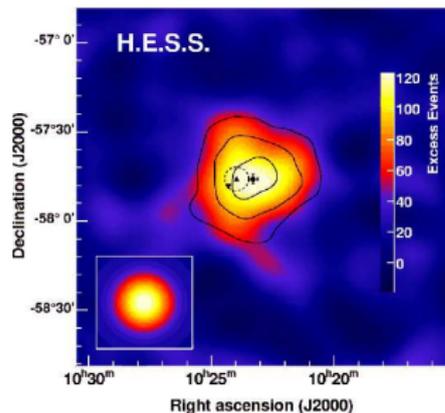
- ▶ First peak shifted to $\phi = 0.25$ for clarity
- ▶ Peak separation: 0.45 ± 0.01
- ▶ Off-pulse region: $0.75 - 1.18$

PLACE IN CURRENT POPULATION OF GAMMA-RAY PULSARS



- ▶ $f = 8.9709 \text{ Hz}$
- ▶ $\dot{f} = -3.09 \times 10^{-11} \text{ Hz s}^{-1}$
- ▶ $\ddot{f} = 6.5 \times 10^{-21} \text{ Hz s}^{-2}$
- ▶ $\tau = 4.6 \text{ kyr}$
- ▶ $\dot{E} = 1.1 \times 10^{37} \text{ erg s}^{-1}$
- ▶ $B_s = 6.6 \times 10^{12} \text{ G}$

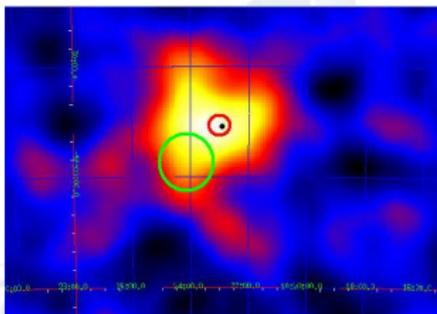
A BRIEF OVERVIEW OF THIS VHE REGION:



HESS reported detection of an extended TeV source near Westerlund 2 star cluster (Aharonian et. al. 2007). Possible VHE emission explanations:

1. Massive WR binary system WR 20a.
2. Young stellar cluster Westerlund 2.
3. Cosmic rays accelerated at their termination shock and interacting with their environment.

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- ▶ Green circle shows Bright Source List location.
- ▶ Red circle shows latest LAT source location.
- ▶ Black dot shows timed pulsar location.

A BRIEF OVERVIEW OF THIS VHE REGION: PART TWO

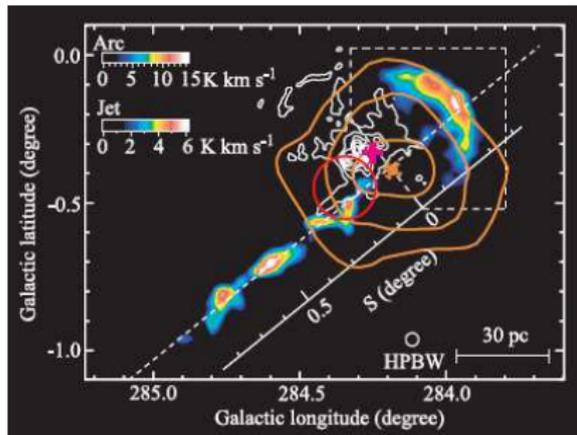
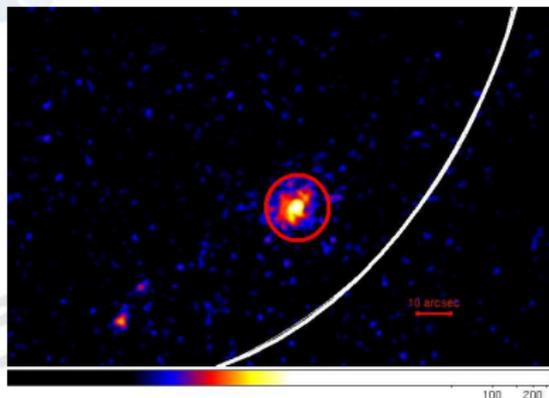
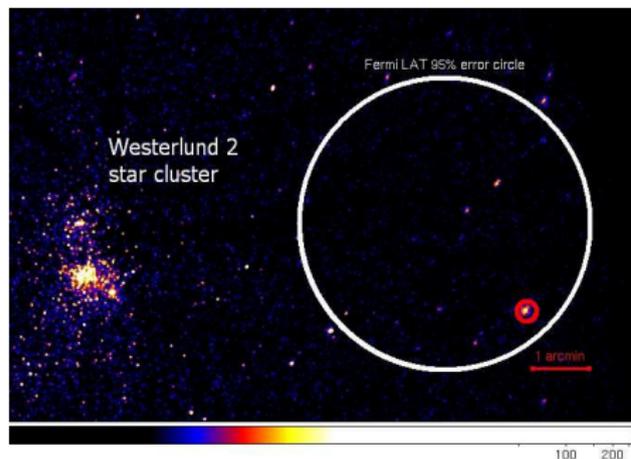


Figure: Distribution of ^{12}CO emission for the arc and jet.

- ▶ Recent paper (Fukui et. al. 2009) observed a jet and arc of molecular gas aligning with this HESS source.
- ▶ Possibly caused by an anisotropic supernova explosion (see Y. Fukui's poster for details).
- ▶ Pulsar source lies near center of HESS source (orange cross), W2 located at pink cross.

CHANDRA IMAGES OF HESS J1023-575

J1022-5746 is located $\sim 8'$ away from W2 core (~ 8 kpc)



- ▶ Chandra 130 ks image reveals faint source CXOU J102302.8-574607 as likely counterpart.
- ▶ Coincident with pulsar location to within $0.1'$.
- ▶ Column density $N_H \sim 1.3 \times 10^{22} \text{ cm}^{-2}$ implies $d \sim 10$ kpc.

SUMMARY / CONCLUSIONS

- ▶ PSR J1022-5746 is the youngest and most energetic gamma-selected gamma-ray pulsar discovered!
- ▶ Observed in radio, no pulsations detected.
- ▶ Discovered in recent blind frequency searches, along with 7 additional pulsars.
- ▶ Chandra analysis reveals faint, distant X-ray source, far from the Westerlund 2 cluster.
- ▶ PSR J1022-5746 is coincident with TeV source HESS J1023-575, suggesting the pulsar contributes to the VHE emission.

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